Flight Demonstration of Novel Atmospheric Satellite Concept

Completed Technology Project (2016 - 2018)

Project Introduction

The Dual-Aircraft Platform (DAP) is a novel concept for achieving a low-cost atmospheric satellite in the lower stratosphere which utilizes a combination of wind and solar energy capture. DAP consists of two glider-like unmanned aircraft connected via a thin, ultra-strong cable. Long duration flight simulations have shown the platform could literally sail without propulsion, using levels of wind shear persistently found near 60,000-ft, and substantially increase the energy available for useful payload operations. #The central objective of the proposed Phase II effort is to perform autonomous proof-of-concept flight demonstrations of the DAP concept using a small-scale prototype at low altitude. Related objectives are develop specific flight maneuvers and mechanisms required for station keeping, and validate the autonomous guidance and control software.#Flight demonstrations of the sailing mode of operation, as well as all other required maneuvers for stratospheric station keeping, will be conducted using the atmospheric onshore wind shear produced at low altitudes (< 500 feet) at Kennedy Space Center's (KSC) Shuttle Landing Facility. Optimal dates/times for flight testing will be selected based on an historical weather assessment. Off-the shelf aircraft will be modified for DAP operation. The aircraft will be remotely controlled by KSC pilots during the first year, and will gradually shift towards complete autonomous flight control in the second year. Flight software will be developed and validated within the hardware-in-the-loop DAP flight simulator at Embry-Riddle Aeronautical University.#Atmospheric satellites represent a long-standing, grand challenge to the aeronautics community, and have enormous potential societal and economic impact. Such airborne platforms are expected to diversify and expand surveillance capabilities (e.g., NASA's earth science missions) and communications bandwidth and availability (e.g., for underserved remote areas of the US, emergency communications), at a fraction of the cost of orbital satellite networks. Successful proof-of-concept DAP flight demonstrations are expected to lead to commercial investment to build a large scale prototype.

Anticipated Benefits

Atmospheric satellites represent a long-standing, grand challenge to the aeronautics community, and have enormous potential societal and economic impact. Such airborne platforms are expected to diversify and expand surveillance capabilities (e.g., NASA's earth science missions) and communications bandwidth and availability (e.g., for underserved remote areas of the US, emergency communications), at a fraction of the cost of orbital satellite networks. Successful proof-of-concept DAP flight demonstrations are expected to lead to commercial investment to build a large scale prototype.

Prototype aircraft with pitot probe and 7-hole air data probe on opposite wings

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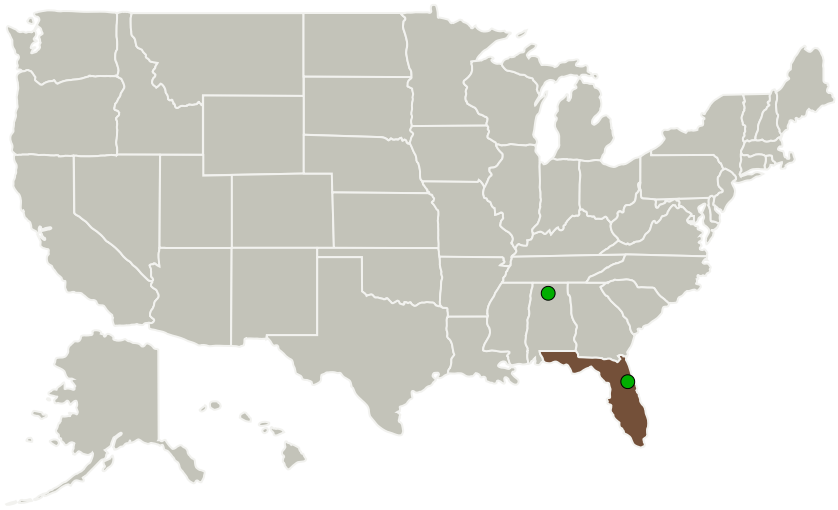
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Embry-Riddle Aeronautical University-Daytona Beach	Lead Organization	Academia	Daytona Beach, Florida
Kennedy Space Center(KSC)	Supporting Organization	NASA Center	Kennedy Space Center, Florida
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Primary U.S. Work Locations
Florida

Project Transitions

July 2016: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Embry-Riddle Aeronautical University-Daytona Beach

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

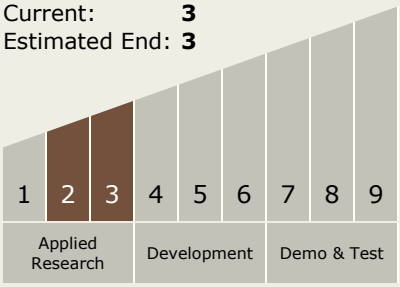
Eric A Eberly

Principal Investigator:

William Engblom

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



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June 2018: Closed out

Closeout Summary: The major focus of the Phase II effort described herein was to develop and demonstrate an aircraft capable of autonomously sailing (i.e., to cruise without propulsion or external assistance), and thereby prove that the dual-aircraft platform (DAP) atmospheric satellite concept is potentially viable. This sailing mode of flight was identified as the #1 enabling technology required for the DAP concept in the Phase I effort. No scientific demonstration of this technology has ever been done to our knowledge. Great strides were made towards development of the enabling technology. A specialized prototype aircraft was developed including a novel cable release mechanism, novel lateron control surfaces, and a highly-accurate onboard wind measurement system. All of these devices were developed in house and validated in flight testing. A specialized flight simulator was constructed and utilized to develop the autonomous flight controller required onboard the aircraft, as support training of pilots for flying aircraft while tethered to a ground vehicle. Software has been developed to provide look-up tables that give the flight condition targets (i.e., 3-D position relative to ground vehicle), speed, orientation, and cable length, based on current wind speed and direction. These tables have been successfully validated in flight simulation and used onboard the aircraft. The aerodynamics of this aircraft were characterized with high fidelity analysis, as needed to produce accurate target sailing flight conditions. The aerodynamics of the cable was also accurately characterized using a novel wind tunnel measurement technique. Finally, novel auto-tuning software has been developed to refine the sailing flight condition targets based on an optimization technique involving doublet maneuvers. Although a real-world demonstration of the sailing mode of flight was not achieved during the Phase II effort, the concept has been further validated using detailed flight simulations and in precursor real-world flight tests. Virtual flights using the auto-tuning software indicate that the prototype aircraft should be able to reach and hold sailing conditions despite moderate levels of turbulence provided there is sufficient mean wind available. Hundreds of flight tests using primarily a dead runway at Deland Municipal Airport, and the long runway at Space Florida's Shuttle Landing Facility, resulted in successful demonstration of the closed-loop autonomous formation flight capability. Future work should include flight testing (and refinement) of the auto-tune software to refine the aircraft orientation targets and achieve and hold the sailing mode of flight. It is also suggested that higher fidelity onboard avionics may be necessary to facilitate sailing by reducing sensor errors. Although the DAP flight simulator, developed within the Matlab-Simulink framework, includes detailed treatment of aircraft/cable aerodynamics, cable dynamics, experimentally-derived propeller-motor thrust curves, and realistic air turbulence, realistic emulation of various sensor errors, more realistic actuator responsiveness, and hardware-in-the-loop testing is highly desirable to improve the fidelity of flight simulation evaluations of the onboard flight software.

Closeout Link: https://www.nasa.gov/feature/flight-demonstration-of-novel-atmospheric-satellite-concept

Technology Areas

Primary:

- TX15 Flight Vehicle Systems
  - TX15.1 Aerosciences
    - TX15.1.6 Advanced Atmospheric Flight Vehicles

Target Destination

Earth

Images

Project Image
Prototype aircraft with pitot probe and 7-hole air data probe on opposite wings
(https://techport.nasa.gov/image/102126)

Links

NASA.gov Feature Article
(https://www.nasa.gov/feature/flight-demonstration-of-novel-atmospheric-satellite-concept)